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Hot summers and heart failure: Seasonal variations in morbidity and mortality in Australian heart failure patients (1994–2005)

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Abstract

Background: There are minimal reports of seasonal variations in chronic heart failure (CHF)-related morbidity and mortality beyond the northern hemisphere.
Aims and methods: We examined potential seasonal variations with respect to morbidity and all-cause mortality over more than a decade in a cohort of 2961 patients with CHF from a tertiary referral hospital in South Australia subject to mild winters and hot summers.
Results: Seasonal variation across all event-types was observed. CHF-related morbidity peaked in winter (July) and was lowest in summer (February): 70 (95% CI: 65 to 76) *vs.* 33 (95% CI: 30 to 37) admissions/1000 at risk ($p<0.005$). All-cause admissions (113 (95% CI: 107 to 120) *vs.* 73 (95% CI 68 to 79) admissions/1000 at risk, $p<0.001$) and concurrent respiratory disease (21% *vs.* 12%, $p<0.001$) were consistently higher in winter. 2010 patients died, mortality was highest in August relative to February: 23 (95% CI: 20 to 27) *vs.* 12 (95% CI: 10 to 15) deaths per 1000 at risk, $p<0.001$. Those aged 75 years or older were most at risk of seasonal variations in morbidity and mortality.
Conclusion: Seasonal variations in CHF-related morbidity and mortality occur in the hot climate of South Australia, suggesting that relative (rather than absolute) changes in temperature drive this global phenomenon.

Keywords: Chronic heart failure; Mortality; Morbidity; Seasonality; Temperature; Hospitalisation

1. Introduction

The phenomenon of seasonal variations in chronic heart failure (CHF)-related morbidity and mortality, characterised by excess events in winter months is well described in the northern hemisphere [1–4]. Conversely, there are few studies focussing on this phenomenon in the southern hemisphere [5]. As such, the impact of potentially important differences in external triggers for fatal and non-fatal acute exacerbations of CHF in various populations and high risk subsets of the CHF population has not been fully explored.

Observed increases in morbidity and mortality in colder months may be explained largely by physiological mechanisms. A lower body temperature on admission has been associated with adverse prognosis in patients with advanced CHF [6]. Whether this association is due to vasoconstriction, an increase in heart failure and blood pressure [7] or a marker of advanced CHF reflecting thermal dysregulation and neurohormonal activation has not yet been determined. Other seasonal variations,

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such as the incidence of respiratory infections may further undermine the fragile state of health of these patients.

In Australia's warm climate, CHF still exerts a substantial burden on the population [8] and health care system [9] with strong anecdotal evidence of winter peaks in hospital admissions due to concurrent respiratory disease and acute HF. Whether this is an accurate picture of the situation in the southern hemisphere, and in particular in southern Australia has not been determined. The impact of high temperatures on CHF morbidity and mortality has to our knowledge not been examined.

The aim of this study was to examine the pattern of morbidity and mortality in patients with CHF living in the Australian state of South Australia (population 1.5 million) over an 11 year period according to the time of the year and weather patterns. A null hypothesis was tested — *that there is no difference in the rate of events in patients with CHF living in South Australia according to the time of year.*

2. Methods

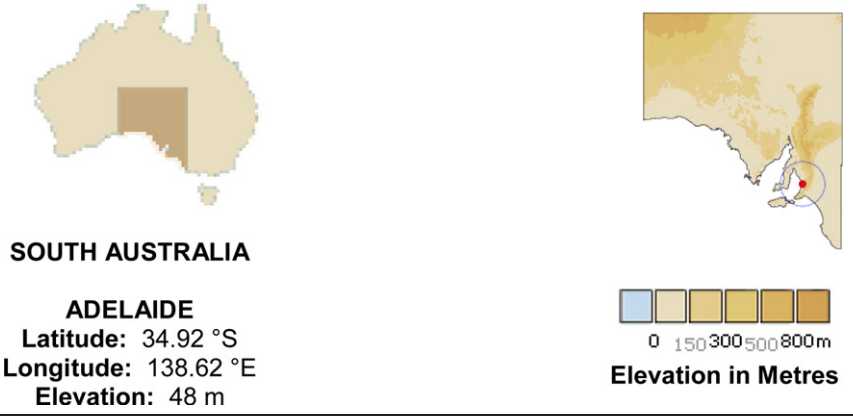
2.1. Setting

The Australian state of South Australia is described as having a Mediterranean-style climate, with hot dry summers (2006 mean maximum temperature was 23.1 °C) and cool winters (2006 mean minimum temperature was 12.1 °C — see Table 1) [10,11]. Some parts of the region experience quite dramatic climates with temperatures as high as 47.4 °C in summer! [10,11] Most of the 1.5 million resident South Australians live in urban areas located in coastal regions. The estimated prevalence of CHF within the total South Australian population (1.9%) [12] is consistent with reports from developed countries.

2.2. Participants, diagnosis and data sources

We undertook a retrospective analysis of longitudinal routinely collected clinical data for a cohort of 2961 patients with a diagnosis of CHF admitted to the largest tertiary referral hospital in the city of Adelaide, South Australia. CHF diagnosis was confirmed by a combination of documented evidence of clinical symptoms equivalent to those included in Framingham criteria [13], echocardiographic data and other cardiac investigations such as coronary angiography (verified by study authors). Patients admitted with a principal diagnosis of CHF between 1 July 1994 and 30 June 2004 to the General Medical Ward or Cardiology unit and discharged alive were recruited to the cohort. Follow-up was performed from index

Table 1
South Australian climate data [10,11]



Season and month of the year		Mean min temperature 1997–2007	Mean max temperature 1997–2007	Average min–max 1997–2007	1997–2007	Mean relative humidity 1997–2007
		°C	°C	°C	mm	%
Autumn	March	15.1	26.2	7.2–41.9	25.5	42
	April	12.3	22.5	4.3–36.9	39.4	47
	May	10.2	19.0	1.5–29.2	59.8	71
Winter	June	8.1	16.1	−0.4–25.4	82.2	62
	July	7.4	15.3	0.4–23.1	74.9	61
	August	8.2	16.7	1.6–30.4	66.6	55
Spring	September	9.6	18.9	2.6–34.3	61.7	52
	October	11.4	21.7	4.7–39.0	46.3	45
	November	13.8	24.8	5.7–42.0	32.1	41
Summer	December	15.5	26.9	8.0–42.5	27.6	40
	January	17.0	28.9	9.2–44.2	20.6	37
	February	17.0	29.3	9.5–44.3	13.2	37
Average for South Australia		12.1	22.2	−0.4–44.3	551.7*	48

* Total annual rainfall.

admission to either death or study census (30 June 2005). These data include all index and subsequent admissions.

Data included is from that collected as part of a clinical cohort registry. Admissions data and patient demographics are from the Royal Adelaide Hospital patient master index. Death data was obtained from official death certificate records from the National Death Index. Comorbidities were derived from the International Classification of Diseases (ICD) coding, and the prescribed medications from pharmacy dispensing data. A sample of records was used to validate comorbidity and prescribed medication data against case notes to ensure its accuracy. Biochemistry data was extracted using linked records from the Institute of Medical and Veterinary Sciences, which is the sole pathology provider to the Royal Adelaide Hospital. Echocardiography data was derived using linked data from the hospital's echocardiogram database, although the availability of this data was limited. Standard bi-plane left ventricular ejection fraction was calculated utilizing Simpson's Method of Discs, following manual tracing of endocardial borders on apical 4-chamber and long axis views.

The Royal Adelaide Hospital is a large tertiary referral centre for all regions of South Australia and there are only a small number of other public hospitals in the state to which these patients would have been readmitted. A review of a sample of readmission data has revealed that few of the readmissions relating to these patients occurred to other South Australian public hospitals.

2.3. Study definitions

For the purpose of this study, CHF was defined according to recently published Australian guidelines [14] as outlined above. The primary outcomes of interest are defined below. Length of stay was calculated to include the number of days the patient occupied a bed inclusive of admission and discharge dates.

CHF-related hospitalisations were identified by a discharge diagnosis coding of CHF in either the first or second diagnostic position for an unplanned admission to hospital. A CHF-related discharge diagnosis code was considered to be one of the following: ICD-9 402.91, 425, 428, 518.4; ICD-10 I11.0, I13.0, I13.2, I25.5, I42, I43, I50, J81. Consistent with previous reports, [1,2] all aetiologic forms of CHF and episodes of pulmonary oedema were included. Previous case note review corresponding to over 1000 patients in this cohort has demonstrated that these codes have greater than 99% specificity for the presence of the Framingham criteria for CHF during the admission [15].

The contribution of respiratory-related morbidity to CHF-related hospitalisations was examined and compared for months with the highest and lowest event rate. We identified unplanned hospitalisations where a CHF-related code and a respiratory code (ICD-9 460–519; ICD-10 J00–J99) were present. Length of stay was also examined.

All-cause hospitalisations included all unplanned admissions to hospital for any cause.

All-cause mortality included deaths from any cause. Data was obtained from official death certificate records linked to patient hospital record numbers from the National Death Index. The underlying mortality rate in the population from which this cohort is derived was considered. South Australian mortality and population data was obtained from the South Australian Department of Health.

2.4. Ethics

All patient data was de-identified prior to analysis. Ethics approval to collect and analyse these data was granted by the relevant institutional ethics committees. This study conformed to the principles outlined in the Declaration of Helsinki.

Table 2
Patient demographics at recruitment [a]

Patient characteristics on recruitment	Total
	n=2961
Male	1490 (50%)
Age (mean±SD)	75±13 years
Country of birth not Australia	1395 (47%)
Discharged to own home	2310 (78%)
Left ventricular ejection fraction (%) (mean±SD)	33.5±13.6%
Proportion with LVEF <40% [b]	67 (68%)
Functional scale (left ventricular function) [b]	
Preserved	222 (30%)
Mild	112 (15%)
Mild–moderate	93 (12%)
Moderate	102 (13%)
Moderate–severe	125 (17%)
Severe	99 (13%)
Biochemistry and haematology (mean±SD)	
Na^+ mmol/L	138.0±4.1
K^+ mmol/L	4.2±0.7
Creatinine mmol/L	135.0±74.0
Hb g/dL	12.4±2.0
Male Hb	12.8±2.1
Female Hb	12.0±1.9
Comorbidities	
Ischaemic heart disease	1415 (49%)
Hypertension	1122 (38%)
Diabetes mellitus	800 (27%)
Atrial fibrillation/flutter	954 (32%)
Chronic obstructive airways disease	500 (17%)
Chronic renal failure	355 (12%)
Peripheral arterial disease	252 (9%)
Cerebrovascular disease	154 (5%)
Asthma	153 (5%)
Dementia	122 (4%)
Anaemia [c]	
Male	344 (52%)
Female	323 (49%)
CHF medications	
ACE inhibitor	1681 (67%)
B-blocker	532 (67%)
Renin–angiotensin system agent [d]	1781 (71%)

[a] Not all clinical data available for all patients, % are calculated according to the number of patients for whom data was available.
[b] Data not available for same number of patients.
[c] Defined according to clinical coding (ICD code).
[d] Excludes aldosterone receptor antagonists.

2.5. Statistical analysis

As data analysis comprises an eleven year study period, during which time there were fatal events, the number of patients at risk of an event (hospitalisation or death) for each month of the year and year of follow-up was calculated according to index admission dates and dates of death until the census date (30 June 2005) allowing adjustment for study entry and death.

The total number of events occurring during each month for the 11 years of the study (inclusive of the index admission) was calculated and divided by the total number of patients at risk of the event for that month over the 11 year study period. These rates are expressed per 1000 patients at risk per month with 95% confidence intervals. The proportion of events and the proportion of concomitant respiratory codes for CHF-related admissions according to the number at risk for the months with the highest and lowest event rates were then compared using Fishers exact test with p values <0.05 considered statistically significant.

Length of stay for CHF-related admissions was analysed by totalling the number of bed-days accumulated for each month over the 11 year study period and dividing this by the total number of CHF-related admissions accumulated for that month over the same period. These averages for the months with the longest and shortest lengths of stay were compared using an independent t-test with p values <0.05 considered statistically significant. A risk ratio (RR) with 95% confidence intervals comparing the highest and lowest event rates according to months of the year was calculated by dividing the total number of events per 1000 at risk accumulated in months with the highest event rate by the total number of events per 1000 at risk accumulated in months with the lowest event rate. Average annual and monthly mortality rates were calculated by averaging the observed monthly mortality rate; these rates were then compared to South Australian mortality rates and attributable risk (%) calculated. Data analysis was performed using SPSS version 15.0.

3. Results

3.1. Clinical and socio-demographic profile

Table 2 provides a summary of the clinical and socio-demographic profile of the 2961 patients that comprise the study cohort. Consistent with reports from other developed countries, patients were elderly and, despite a high comorbid burden, predominantly lived independently in their own home. Not all patients were born in Australia, of the 47% born overseas; the majority (88%) emigrated from Europe in the first two decades following World War II. The majority of the cohort resided in metropolitan and urban areas, with a small number recording their residential address in remote and rural areas of the State.

3.2. Pattern of chronic heart failure-related unplanned hospitalisations (1994 to 2005)

Between 1 July 1994 and 30 June 2005 (mean study follow-up of 36±32 months) a total of 2782 patients (94% of

Table 3
Seasonal variations in the rate of CHF-related hospitalisations and concurrent respiratory disease

	Total events	Average monthly event rate [a]	High *vs.* low months [b]	Observed *vs.* expected rate [c]	Concurrent respiratory diagnosis (%)	
		/1000 at risk (95% CI)	/1000 at risk (95% CI)	p value		p value: low *vs.* high month
All (n=2961)	5306	50 (45 to 54)	July: 70 (65 to 76) February: 33 (30 to 37)	<0.001 <0.001	21 12	<0.001
Female (n=1471)	2652	49 (44 to 56)	July: 75 (67 to 83) March: 34 (29 to 40)	<0.001 <0.001	20 15	NS (0.204)
Male (n=1490)	2654	50 (44 to 56)	July: 66 (59 to 74) February: 32 (27 to 37)	<0.001 <0.001	23 14	NS (0.021)
Aged<75 years (n=1262)	2033	35 (30 to 40)	July: 47 (41 to 54) February: 24 (20 to 29)	0.002 0.002	17 10	NS (0.105)
Aged≥75 years (n=1699)	3273	67 (60 to 75)	July: 98 (38 to 51) February: 44 (89 to 108)	<0.001 <0.001	24 14	0.004
Female aged<75 years (n=469)	765	32 (26 to 41)	September: 45 (37 to 56) February: 23 (17 to 31)	0.031 NS (0.066)	19 7	0.043
Female aged≥75 years (n=1002)	1887	63 (54 to 73)	July: 100 (89 to 113) March: 41 (34 to 49)	<0.001 <0.001	21 12	0.031
Male aged<75 years (n=793)	1268	37 (30 to 44)	August: 47 (39 to 55) February: 25 (20 to 31)	NS (0.054) 0.010	15 12	NS (0.535)
Male aged≥75 years (n=697)	1386	74 (62 to 88)	August: 98 (84 to 114) February: 44 (35 to 55)	0.015 <0.001	31 16	0.020

[a] Average monthly event rate was calculated by dividing the average accumulated number of patients at risk per month by the average accumulated events per month.
[b] $p<0.001$ for all comparisons of low *vs.* high monthly rates.
[c] Difference between the calculated average monthly event rate and the observed (for high or low months) monthly event rate.

total cohort) were discharged from hospital with a diagnosis of CHF in the first or second diagnostic position. These 2782 patients accumulated 5306 CHF-related admissions to hospital (mean 1.9±1.7 admissions per patient), of which 48% were recurrent admissions. The underlying expected rate of admissions was 50 (95% CI 45 to 54) per 1000 patients at risk per month. The mean length of stay for these admissions was 8.8±8.2 days with a total of 46,669 bed-days accumulated.

Seasonal variation in CHF-related morbidity was observed (see Table 3). Specifically, a significantly higher crude rate of unplanned admissions for CHF according to the number of patients at risk was observed in July (winter) with the lowest rate recorded in February (summer): 70 (95% CI: 65 to 76) *vs.* 33 (95% CI: 30 to 37) admissions per 1000 patients at risk ($p<0.005$) respectively. Similar trends were observed across all sub-analyses and event rates were consistently significantly different between warmer and cooler months. Fig. 1 depicts the CHF-related unplanned hospitalisation rate according to sex.

The proportion of concomitantly coded respiratory and CHF-related admissions was consistently higher in months with the highest event rate (19%–31% of admissions) relative to months with the lowest event rate (7%–16% of admissions). Table 3 shows that the majority of event rates in the winter months were statistically higher than those recorded in the warmer summer months.

Overall, length of stay did not vary significantly for those months with the highest and lowest rates of CHF-related hospitalisations. However, particular sub-groups (males, those aged ≥75 years, males and females aged ≥75 years) experienced significant variation in length of stay between months. For males, the longest length of stay was observed in August, with a mean length of stay of 9.0±1.6 days relative to January, 7.5±1.5 days ($p=0.027$). A similar pattern was seen in those aged ≥75 years: August, 9.0±1.8 days *vs.* January, 7.1±1.4 days ($p=0.011$). This trend continued for males aged ≥75 years: July, 9.2±3.0 days *vs.* January, 6.3±1.1 days ($p=0.007$). Conversely, a different seasonal pattern was seen for females aged ≥75 years, with November observed to have the longest length of stay relative to July, 11.3±6.2 days *vs.* 6.8±2.0 days ($p=0.040$). This group also experienced the greatest monthly variation in the length of stay for CHF-related hospitalisations.

3.3. Pattern of all-cause unplanned hospitalisation (1994 to 2005)

Over the 11 year period of follow-up, this cohort accumulated 9342 unplanned admissions to hospital for any cause, totalling 90,058 bed-days. Seasonal variation in the pattern of these admissions was observed (see Table 4). July was consistently observed to have the highest rate of all-cause unplanned hospitalisations with the exception being males aged ≥75 years, for whom the highest rate of admissions was observed in August. The lowest hospitalisation rates were recorded in either December or February.

3.4. Pattern of all-cause mortality (1994 to 2005)

Over the same period of follow-up, 2010 patients (68%) died. Seasonal variation in mortality was observed: a significantly higher crude mortality rate was recorded when adjusted for the number of patients at risk in August

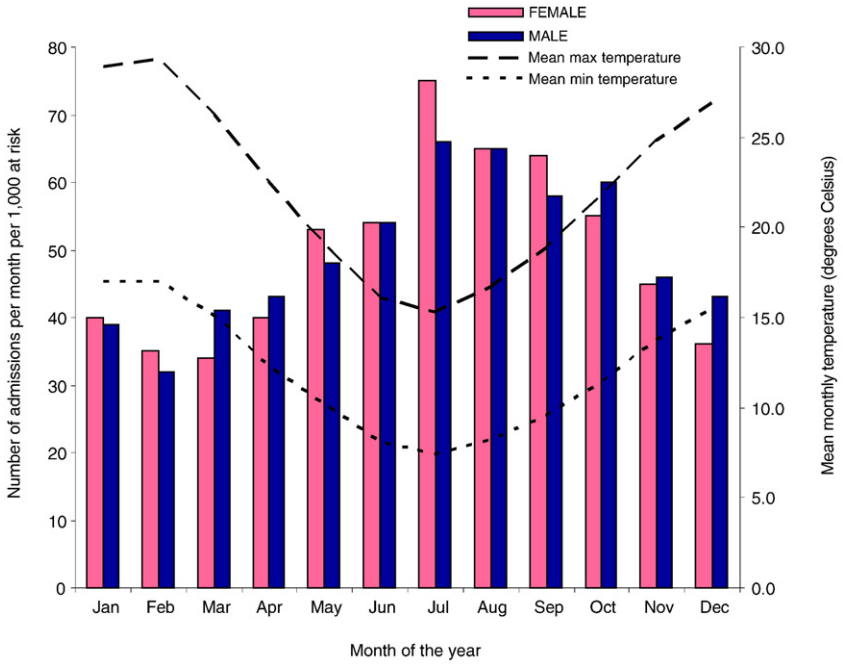


Fig. 1. CHF-related hospitalisation rate according to month of the year. Graph depicts mean high and low temperatures for the month [10,11].

Table 4
Seasonal variations in the rate of all-cause hospitalisations

	Total events	Average monthly event rate [a]	High *vs.* low months [b]	Observed *vs.* expected rate [c]
		/1000 at risk (95% CI)	/1000 at risk (95% CI)	*p* value
All (n=2961)	9342	87 (82 to 93)	July: 113 (107 to 120) February: 73 (68 to 79)	<0.001 0.001
Female (n=1471)	4583	86 (78 to 94)	July: 116 (107 to 126) December: 66 (59 to 74)	<0.001 <0.001
Male (n=1490)	4759	89 (81 to 98)	July: 111 (102 to 120) February: 70 (63 to 78)	0.001 0.001
Aged<75 years (n=1262)	3560	61 (55 to 61)	July: 78 (70 to 86) December: 50 (45 to 57)	0.001 0.021
Aged≥75 years (n=1699)	5782	119 (109 to 129)	July: 156 (145 to 168) February: 97 (88 to 106)	<0.001 0.001
Female aged<75 years (n=469)	1326	56 (47 to 67)	July: 72 (61 to 84) December: 43 (35 to 53)	0.041 0.047
Female aged≥75 years (n=1002)	3257	109 (97 to 122)	July: 151 (137 to 166) December: 84 (74 to 96)	<0.001 0.003
Male aged<75 years (n=793)	2234	64 (56 to 74)	July: 82 (72 to 92) February: 54 (46 to 63)	0.012 NS (0.084)
Male aged≥75 years (n=697)	2525	134 (118 to 152)	August: 164 (147 to 184) February: 99 (85 to 115)	0.015 0.002

[a] Average monthly event rate was calculated by dividing the average accumulated number of patients at risk per month by the average accumulated events per month.
[b] $p \leq 0.001$ for all comparisons of low *vs.* high monthly rates.
[c] Difference between the calculated average monthly event rate and the observed (for high or low months) monthly event rate.

relative to February: 23 (95% CI: 20 to 27) *vs.* 12 (95% CI: 10 to 15) deaths per 1000 patients at risk respectively, $p<0.001$ (see Table 5). Fig. 2 depicts seasonal trends in all-cause mortality according to age and sex. The risk of a patient dying in the cooler winter months was double that of dying in the hot summer months (RR 2.0, 95% CI 1.7 to 2.5).

The calculated average annual mortality rate for the general South Australian population for this period (1994 to 2005) was 8 deaths per 1000 at risk, for those aged ≥75 years it was 73 deaths per 1000 at risk (or 6 deaths per month per 1000 at risk). The annual mortality rate for males and females was 8 *vs.* 7 deaths per 1000 at risk respectively.

Table 5
Seasonal variations in the rate of all-cause mortality

	Total events	Average monthly event rate [a]	High *vs.* low months [b]	Observed *vs.* expected rate [c]
		/1000 at risk (95% CI)	/1000 at risk (95% CI)	*p* value
All (n=2961)	2010	19 (16 to 22)	August: 23 (20 to 27) February: 12 (10 to 15)	0.040 <0.001
Female (n=1471)	1009	19 (15 to23)	September: 24 (20 to 29) February: 12 (9 to 15)	NS (0.078) 0.004
Male (n=1490)	1001	19 (15 to 23)	July: 26 (22 to 31) February: 13 (9 to 16)	0.019 0.021
Aged<75 years (n=1262)	707	12 (9 to 16)	July: 17 (14 to 21) February: 7 (5 to 10)	0.039 0.013
Aged≥75 years (n=1699)	1303	27 (22 to 32)	August: 34 (29 to 41) February: 18 (14 to 23)	0.045 0.005
Female aged<75 years (n=469)	244	10 (7 to 16)	September: 14 (10 to 20) February: 6 (3 to 10)	NS (0.241) NS (0.069)
Female aged≥75 years (n=1002)	765	26 (20 to 33)	September: 32 (26 to 40) February: 16 (12 to 22)	NS (0.175) 0.018
Male aged<75 years (n=793)	463	13 (10 to 18)	July: 20 (16 to 26) March: 8 (5 to 12)	0.038 0.030
Male aged≥75 years (n=697)	538	29 (22 to 38)	August: 39 (31 to 50) February: 20 (15 to 29)	NS (0.091) NS (0.135)

[a] Average monthly event rate was calculated by dividing the average accumulated number of patients at risk per month by the average accumulated events per month.
[b] $p \leq 0.005$ for all comparisons of low *vs.* high monthly rates.
[c] Difference between the calculated average monthly event rate and the observed (for high or low months) monthly event rate.

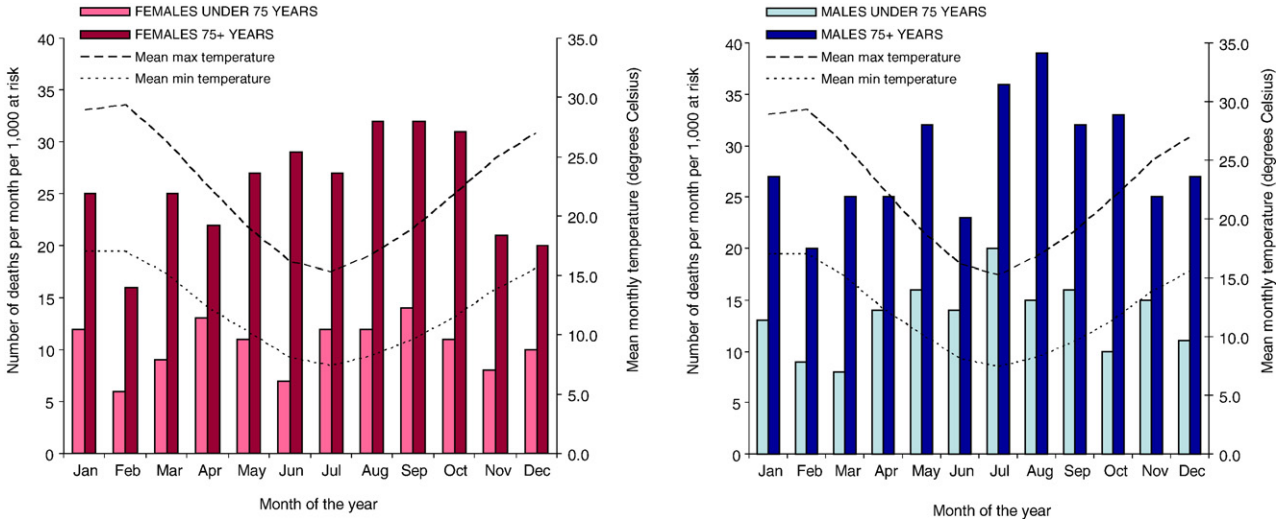


Fig. 2. All-cause mortality rate according to sex and months of the year. Graphs depict mean high and low temperatures for the month [10,11].

For the patients in this cohort, the calculated average annual crude mortality is 228 deaths per 1000 at risk per year (19 deaths per 1000 at risk per month, see Table 5). In those aged ≥75 years we would expect 324 deaths per year per 1000 at risk (27 deaths per month per 1000 at risk). There is a remarkable difference between the expected monthly mortality for South Australians compared with those included in this cohort. The attributable risk (%) for CHF for those aged ≥75 years included in this cohort is 77.8%.

4. Discussion

This represents one of the first studies to formally identify the phenomenon of seasonal variations in CHF-related morbidity and mortality in a predominantly Mediterranean-style climate comprising mild winters and warm to hot summer months. A seminal report from France incorporated data from a similar climate but also included data from milder northern regions of France, [4] whilst a more comparable study in Spain involved a smaller patient population [2]. Consistent with these and other reports from the northern hemisphere [1,3] we identified a significant winter peak and summer trough in CHF-related events and all-cause mortality and morbidity in patients with CHF. Specifically, we made two key observations: 1) that CHF patients living in South Australia experience the same seasonal differences in CHF-related morbidity and all-cause mortality as observed in northern hemisphere CHF patient populations, and 2) that these CHF patients appear to be able to tolerate appreciably hot temperatures in the summer months (temperature range 8.0 °C to 44.3 °C) [10,11], a period which was associated with the lowest event rates in this CHF patient cohort.

Boulay et al. [4] reported a 20% peak above average in CHF-related mortality in January and 15% below average for August [4]. CHF-related hospitalisations followed a similar trend [4]. The typical winter and summer temperatures that these patients were exposed to were colder than the typical winter and summer temperatures to which participants in this current cohort were exposed. For example, the mean daily maximum temperature for Paris in January over the period 1971 to 2000 was 6.9 °C and in August, 24.6 °C [16]. A Spanish study reported that CHF-related hospitalisation rate peaked in January (25% above average) and was one third less than the average in August [2]. These Spanish CHF patients may have been exposed to a slightly warmer climate, with mean daily maximum of 9.7 °C in January and mean daily maximum of 30.7 °C in August [16]. In this South Australian-based study, we found that the CHF-related hospitalisation rate peaked in the equivalent winter month of July (40% above the expected monthly rate) and was just over one third less in the summer month of February. The mean daily summer temperature to which these CHF patients residing in South Australia were exposed was a minimum of 15.5 °C to a maximum of 29.3 °C (1997–2007 summer temperatures ranged from 8.0 °C to 44.3 °C), in winter the mean daily minimum temperature was 7.4 °C to 16.7 °C (1997–2007 winter temperatures ranged from −0.4 °C to 30.4 °C) [10,11].

One prior southern hemisphere study of seasonal variation in events in CHF patients from Argentina found that CHF-related hospitalisations and in-hospital deaths peaked in July (mean maximum daily temperature 21 °C) and were lowest in April (mean daily temperature 13 °C) [5,17].

Studies of seasonal variations in morbidity and mortality in CHF patient populations living in notably cooler northern hemisphere climates (Scotland and Quebec) have also reported similar winter peaks and summer troughs [1,3].

Relative to these South Australian findings and despite considerable differences between the two climates, Stewart et al. [1] reported similar seasonal variations in event rates in the Scottish population. CHF hospitalisations, concurrent respiratory disease and all-cause mortality across the whole population exhibited seasonal variation [1]. Consistent with the current

report, greatest variation in CHF-related hospitalisation rate and all-cause mortality (i.e. those most vulnerable to climatic variations) was observed in those aged ≥75 years. The temperatures to which the Scottish population was exposed are dramatically cooler than those to which our South Australian CHF patients were exposed. In January, the mean (1971–2000) maximum daily temperature in Scotland was 6.2 °C and in July, the mean maximum daily temperature was 18.8 °C [16].

To date, published Australian reports of seasonality in cardiovascular events have been limited to coronary artery disease [18–21]. The most recent study reported seasonal variation in coronary artery deaths, with a peak observed in July similar to our findings for all-cause mortality and hospitalisations with the lowest event rate observed in summer months [20].

When considering similar patterns of seasonal variations across several different patient populations and climates, our data supports the hypothesis that it is the "relative" difference in temperature driving the seasonal variation, rather than an "absolute" temperature difference. Even though the temperature experienced by these South Australian CHF patients in summer is much higher and the winter temperature considerably warmer than that experienced by northern hemisphere populations, the same summer trough and winter peak in event rates are observed. It seems that event rates peak when temperatures fall to their lowest point and the lowest rates are observed when temperatures are at the warmest. It could, therefore, be hypothesised that there is no "ideal" temperature range for CHF patients, more that there is an ideal temperature range for each patient population. A pertinent review on climate change and human health [22] highlights that populations typically display an optimum temperature and that mortality rates rise at temperatures which occur outside this comfort zone.

The current results show evidence of acclimatisation in these patients. Whilst the majority were born in Australia, 47% were immigrants to Australia, mainly from Europe. Over a period of 30 or more years up to a lifetime these patients have adapted to the South Australian climate and even the physical vulnerability afforded by CHF has not exposed them to increased risk of events in hot summer months. The forecast increase in average world temperature (1.4–5.8 °C) by 2100 [22] raises concerns about the impact of heat on fragile patient populations. There are several published reports of increased mortality in heat waves [23] some of which examine the impact on vulnerable populations such as patients with cardiovascular disease [24] or CHF [25].

We have seen from these data that greater seasonal variation was observed in CHF-hospitalisation rates relative to all-cause hospitalisation rates. There may be a number of reasons for this observed difference. During the winter period we have seen that the proportion of concurrent respiratory illness is much higher than at other periods. Therefore, it is more likely that an admission to hospital for a patient with CHF with pneumonia for example, would be coded with CHF and respiratory disease discharge codes, thus making CHF-related admission rates more sensitive to specific seasonal morbidity. Furthermore, we limited our identification of CHF-related admissions to the first or second discharge code, and hence admissions with a CHF-related discharge code beyond the second position would be counted as all-cause admission so the seasonal variation observed in all-cause hospitalisations may not be due to non-CHF-related morbidity, but may represent instances of CHF-related hospitalisation with a CHF-related discharge code in the third or greater position. There may also be healthcare workforce issues and lifestyle factors which may account for low admission rates seen in summer months.

What are the potential mechanisms underlying the apparent paradox of reduced CHF-related morbidity and mortality in the hot Australian summer given that empirical and anecdotal evidence suggests that heat tolerance may be impaired in patients with cardiovascular disease and in particular, in patients with CHF?

Two recent studies offer further clarification into the physiological effects of heat stress on thermoregulatory responses in CHF patients [26,27]. Cui et al. found that cutaneous vasodilator responses to heating were significantly reduced in patients with CHF, whereas sweating responses were not impaired [26]. In a small Australian study, CHF patients exhibited impaired thermoregulatory responses to heat exposure, possibly facilitated by lower skin blood flow [27]. The seasonal trends observed in this current cohort raise the question of whether impaired thermoregulation can increase the risk of morbidity and mortality in these patients. Both studies [26,27] exposed patients to temperatures of up to 38 °C for periods of up to 90 min. It is not unheard of for Adelaide, the capital of South Australia, to experience several continuous days of temperatures above 35 °C with little relief overnight, these "heat waves" tend to occur in January and February. Whilst some tolerance to these high temperatures may be explained by air conditioning, it is unlikely that all 2961 patients lived in air conditioned accommodation; in fact, these results seem to suggest that there may be some benefit of hotter weather for those with CHF. Though limited, there is some research in favour of the use of heat for patients with CHF with suggestions that thermal hydrotherapy [28] or saunas [29] may improve quality of life and CHF symptoms.

An increase in event rates in colder winter months has been postulated to be due to increased haemodynamic stress and neurohormonal activation [30] which may lead to myocardial ischaemia and precipitation of cardiac arrhythmias [31] and acute heart failure [32]. The incidence of respiratory infections increases in colder months and the contribution of this concurrent illness on already fragile patients with CHF cannot be underestimated.

There are several clinical implications of these findings. Along with previous reports, these findings provide evidence for increasing the intensity of CHF-management strategies prior to periods with expected higher event rates. The importance of pneumococcal and influenza vaccination in this patient population is highlighted. Our results further emphasise the burden of CHF born by the hospital system

during the winter months and warrant consideration of the potential cost-savings of alternative strategies to reduce this financial and resource burden. Such strategies must be aimed at reducing the vulnerability of these patients to cold weather and concurrent respiratory infection. Further research into the physiological mechanisms behind thermoregulation in CHF patients needs to be conducted as the temperature mortality/morbidity relationship most likely varies between climatic zones and patient populations.

There are a number of limitations that require comment. Firstly, unlike other reports, these data are based on a cohort of patients from a single tertiary institution. We do however have more detailed clinical data than similar reports published previously. Whilst this cohort was established to examine morbidity and mortality in these patients, it was not prospectively established to examine the current hypothesis; therefore we do not have data relating to factors which may influence susceptibility to cold and heat such as body mass index, smoking status, type of residence, heating or cooling of patients' homes and socioeconomic status. Moreover, we did not consider our findings in relation to air pollution data, barometric pressure or humidity. CHF-related hospitalisations were identified using ICD discharge coding, and though shown to be useful and accurate in identifying hospitalisations related to CHF, discharge codes have been shown to underestimate hospital events related to CHF in a UK population [33]. Therefore, it is likely that we may have missed some CHF-related events in this cohort or that these may have been classified as all-cause admissions. We had limited access to echocardiogram reports for these patients, thus we were reliant on diagnosis of CHF confirmed by angiography or clinical diagnosis determined by a cardiologist according to the Framingham criteria. Consistent with other reports, we had limited data to differentiate between patients with predominantly systolic heart failure compared to those with preserved systolic function.

5. Summary

Despite these limitations we have demonstrated clear seasonal variations in CHF-related morbidity and mortality in a cohort of patients living in South Australia, and therefore, exposed to relatively mild winters and warm to hot summers. These data suggest that relative (rather than absolute) changes in temperature and climatic conditions drive this global phenomenon. Attention needs to be paid to the impact of hot weather on patients with CHF; however, these data suggest that warmer temperatures may not be as detrimental for patients with CHF as previously thought.

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